Polychlorinated Dibenzo-*p*-dioxins, Polychlorinated Dibenzofurans, and Coplanar Polychlorinated Biphenyls

General Information

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans are two similar classes of chlorinated aromatic chemicals that usually are produced as contaminants or byproducts. They have no known commercial or natural use. Processes that contribute to their production include the incineration or burning of waste; pulp and bleaching processes used in pulp and paper mills; and the chemical syntheses of trichlorophenoxyacetic acid, hexachlorophene, polychlorinated biphenyls, vinyl chloride, and pentachlorophenol. As a result of man-made environmental release and contamination, most soil and water samples reveal trace amounts of polychlorinated dibenzo-*p*-dioxins and dibenzofurans when advanced analytical techniques are applied. Releases from industrial sources have decreased approximately 80% since the 1980s. The largest release of these chemicals today is the open burning of household trash and municipal trash, landfill fires, and agricultural and forest fires. In the environment, these chemicals usually occur as a mixture of congeners (i.e., compounds that differ by numbers and positions of chlorine atoms attached to the dibenzo-*p*-dioxin or dibenzofuran structures).

People are exposed primarily through foods that are contaminated with polychlorinated dibenzo-*p*-dioxins and dibenzofurans as a result of the accumulation of these substances in the food chain and in high-fat foods, such as dairy products, eggs, animal fats, and some fish. People have also been exposed through industrial accidents (e.g., an explosion in a factory in Seveso, Italy), use of accidentally contaminated cooking oils (e.g., as occurred in Yusho in Japan and Yu-cheng in Taiwan), spraying of herbicides contaminated with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD, as Agent Orange in Vietnam), and burning of or exposure to polychlorinated biphenyls contaminated with polychlorinated dibenzofurans, such as in old electrical tranformers. Workplace exposures are rare, and generally recognized standards for external exposure have not been established**.** Information about environmental levels and health effects is available online from ATSDR http://www.atsdr.cdc.gov/toxprofiles.   The U.S. EPA provides updated exposure and health assessments online at http://www.epa.gov/ncea/pdfs/dioxin/.

Effects in people have been observed as a result of industrial or accidental exposures involving large quantities of these chemicals. Chloracne, biochemical liver-test abnormalities, elevated blood lipids, fetal injury, and porphyria cutanea tarda have been reported in many of the studies. In some of these exposures, hormonal, neurologic, and immunologic effects have also been reported although with varying consistency (Michalek et al., 1999; Halperin et al., 1998; Jung et al., 1998, Matsuura et al., 2001). Congenital anomalies and intrauterine growth retardation were observed in offspring of mothers exposed to cooking oil contaminated with electrical oil containing polychlorinated biphenyls and dibenzofurans. Dioxins and polychlorinated biphenyls may possibly be associated with abnormal neurological status in newborns (Koopman-Esseboom et al., 1997).

Further, carcinogenic, genetic, reproductive, and developmental effects have been observed in many animal studies although species differ dramatically in sensitivity to these chemicals.   The Institute of Medicine has determined that human epidemologic evidence is sufficient for causally linking exposure to herbicides contaminated with TCDD to increased risk for non-Hodgkin's lymphoma, Hodgkin's lymphoma, and soft-tissue sarcoma (Institute of Medicine, 2000). Generally, the increased risk for these cancers occurs in association with large exposures encountered in contaminated occupational settings or massive unintentional releases.

Because general population exposure to these chemicals occurs as exposure to a mixture of different congeners, effects due to specific individual congeners are difficult to determine (Masuda et al., 1997; Masuda 2001). Clearly, however, many of the effects are mediated through an interaction with the aryl hydrocarbon receptor (AHR), particularly the induction of gene expression for cytochromes P450, CYP1A1, and CYP1A2. Dioxins and furans require three or four lateral chlorine atoms on the dibenzo-*p*-dioxin or dibenzofuran backbone to bind this receptor. The rank order of interaction with the AHR receptor by degree and position of chlorination is similar for both the dioxin and furan series. In addition, natural and endogenous substances may antagonize or add to the effects at this receptor. The variation in toxicity among

the dioxins and furans and the effect at the AHR is 10,000-fold, with TCDD being the most potent. Because of its exceptional potency and because it is the most studied dioxin or furan, TCDD is separately classified by the IARC as a known human carcinogen (Group 1) and by NTP as a known human carcinogen. Other poly-chlorinated dibenzo-*p*-dioxins and dibenzofurans have not been studied sufficiently to determine their carcino-genicity (IARC).

Many of the other polychlorinated dibenzo-*p*-dioxins and dibenzofurans and certain polychlorinated biphenyls are less potent than TCDD but vary considerably in their respective concentrations. Each congener can be as-signed a potency value relative to TCDD (toxic equiva-lency factor [TEF]). When a TEF is multiplied by the congener concentration level, a toxic equivalency (TEQ) value is obtained. Thus, the toxic contribution of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and certain polychlorinated biphenyls can then be compared. The sum of all TEQs in a specimen (total TEQ) can be used to compare specimens. The coplanar polychlori-nated biphenyls (unsubstituted at any ortho position, allowing a planar three-dimentional structure) and the mono-ortho-substituted polychlorinated biphenyls (a chlorine atom at one of the ortho positions) can also act through mechanisms thought to be similar to those described for the dioxins and furans. The coplanar-polychlorinated biphenyls have less potency, but their concentrations are often much higher than concentrations of TCDD (Kang et al., 1997; Patterson et al., 1994), so their relative contribution to the total TEQ is potentially sizable. For a discussion of the other polychlorinated biphenyls, see the section titled "Polychlorinated Biphenyls."

*Interpreting Levels of Lipid-Adjusted Serum Polychlori-nated Dibenzo-*p-*dioxins, Polychlorinated Dibenzo-furans, and Coplanar Polychlorinated Biphenyls Reported in the Tables*

Serum lipid-based measurements of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar poly-chlorinated biphenyls were measured in a subsample of NHANES 1999-2000 participants aged 12 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. It is estimated that human serum lipid-based levels of polychlorinated dibenzo-*p*-dioxins and

dibenzofurans have decreased by more than 80% since the 1980s (Aylward and Hays, 2002). The generally low values reported here support that observation. Only the following polychlorinated dibenzo-*p*-dioxins, dibenzo-furans and coplanar polychlorinated biphenyls (IUPAC nomenclature) had detection rates greater than 5% in the NHANES 1999-2000 subsample:

1,2,3,4,6,7,8,9-octachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin
1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin
1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin
1,2,3,7,8-pentachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-heptachlorodibenzofuran
1,2,3,4,7,8-hexachlorodibenzofuran
1,2,3,6,7,8-hexachlorodibenzofuran
2,3,4,7,8-pentachlorodibenzofuran
coplanar polychlorinated biphenyls 169 and 126.

In addition, mono-ortho substituted PCBs 118 and 156 also had detection rates above 5% (discussed in the section titled "Polychlorinated Biphenyls").

In keeping with results from other reports (Papke et al., 1998), this NHANES 1999-2000 subsample shows that the more highly chlorinated dioxin and furan congeners, several coplanar polychlorinated biphenyls (listed above), and some of the mono-ortho substituted poly-chlorinated biphenyls (see the section titled "Polychlori-nated Biphenyls") are the main contributors to the human body burden and total TEQ. Higher concentrations of these congeners are due to their greater presence in the food chain, resistance to metabolic degradation, and greater solubility in body fat. For example, people consuming fish from the Great Lakes have had modestly increased mean concentrations of dioxins and furans that are several times the population background values (Falk et al., 1999; Anderson et al., 1998; Hanrahan et al., 1999). The patterns of individual congeners in a speci-men when present at high concentrations can represent the exposure source in some cases, but are less predictive at low levels due to mixing of many low-level sources before ingestion and the differential effect of elimination on different congeners from the body.

Differences in levels of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar polychlorinated biphenyls that are present in serum are due in part to exposure but also result from differences in absorption,

tissue distribution, metabolism, and elimination. Half-lives for all the dioxins and furans vary from 3-19 years, with TCDD estimated at around 7 years (Geyer et al., 2002). The more highly chlorinated congeners are retained longer and accumulate more in the body. Because these chemicals are stored in adipose tissue, they will have longer residence times in people with higher amounts of body fat (Tepper et al., 1997). Current levels may be influenced by both past (fat-stored chemicals) and recent exposures. Several studies have shown that serum levels of dioxins and furans increase with the age of the individual (Falk et al., 1999). In this *Report*, 1,2,3,4,6,7,8,9-octachlorodibenzo-*p*-dioxin, 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin and 1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin levels were higher in adults aged 20 years and older than in people aged 12-19 years when compared at the higher percentiles.

The most potent of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar polychlorinated biphenyls is TCDD. In the current NHANES 1999-2000 subsample, the rate of detection was 0.7%. The LOD varied because of available specimen volumes. The average LOD was 4.8 picograms/gram (pg/gram) of lipid (standard deviation 1.8 pg/gram of lipid). Background levels in the United States and other developed countries have fallen to levels near or below these LODs (Papke et al., 1998; Calvert et al., 1996). These levels are much lower than those for chemical-production workers when they were examined 15 years after workplace exposure had ceased (median serum TCDD concentration = 68 pg/gram of lipid) (Calvert et al., 1996). The level of TCDD in fat and serum is also known to increase with age of the individual (Luotamo et al., 1991).

Levels in this *Report* are far below those associated with the occupational and unintentional exposures that produce health effects. There are no firmly established relationships between serum lipid-based concentrations and effects in people. Studies of industrial and accidental exposures suggest that concentrations of at least 800 pg/gram of lipid might be necessary to induce chloracne, a specific effect, although levels in the thousands of pg/gram of lipid do not always produce this effect

Table 76. Polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and coplanar polychlorinated biphenyls

Polychlorinated dibenzo-*p*-dioxins	CAS number	IUPAC number
1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD)	3268-87-9	
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD)	35822-46-9	
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD)	57653-85-7	
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD)	19408-74-3	
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD)	40321-76-4	
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)	1746-01-6	
Polychlorinated dibenzofurans	**CAS number**	
1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)	39001-02-0	
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	67562-39-4	
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	70648-26-9	
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	57117-44-9	
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	72918-21-9	
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	57117-41-6	
2,3,4,6,7,8-Hexchlorodibenzofuran (HxCDF)	60851-34-5	
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	57117-31-4	
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	51207-31-9	
Polychlorinated biphenyls (coplanar)	**CAS number**	**IUPAC number**
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	32774-16-6	PCB 169
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	57465-28-8	PCB 126
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	70362-50-4	PCB 81

(Mocarelli et al., 1991). The few studies showing effects in people after large unintentional exposures have demonstrated concentrations ranging from several hundred to the tens of thousands of pg/gram of lipid (Masuda 2001; Masuda et al., 1998; Mocarelli et al., 1991).

Finding a measurable amount of one or more of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, or coplanar biphenyls in serum does not mean that the level of one or more of these causes an adverse health effect. Whether the concentrations reported here are a cause for health concern is not yet known; more research is needed. These levels provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, or coplanar biphenyls than those found in the general population. These data will also help scientists plan and conduct research on exposure and health effects.

Measuring polychlorinated dibenzo-*p*-dioxins, dibenzofurans, or coplanar biphenyls at these levels in serum is possible because of advances in analytical chemistry. As seen in other recent population studies, pooling of approximately 50 or more specimens is required to have adequate amounts of sample to detect the general population levels of dioxin-like compounds that are needed to properly estimate a TEQ. Because of limited availability of serum volumes and the low levels detected in the NHANES 1999-2000 population, TEQ values are not estimated from this analysis of individual samples. Future plans for the *Report* include the analysis of pooled samples to significantly lower the LOD for these compounds and allow calculation of TEQ values.

Table 77. 1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	405 (369-446)	674 (598-741)	913 (806-986)	1921
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	421 (<LOD-597)	667
20 years and older	*	< LOD	< LOD	< LOD	445 (403-484)	704 (625-800)	948 (846-1030)	1254
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	515 (449-580)	704 (579-806)	919
Females	*	< LOD	< LOD	< LOD	503 (446-538)	802 (689-927)	1010 (948-1130)	1002
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	416 (367-496)	702 (582-916)	940 (737-1280)	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	444 (380-497)	741 (594-904)	1120 (799-1560)	411
Non-Hispanic whites	*	< LOD	< LOD	< LOD	390 (345-443)	625 (569-727)	848 (731-982)	721

< LOD means less than the limit of detection, which averaged 145 pg/g of lipid (SD 46.0, maximum value 329).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 78. 1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	58.2 (<LOD-63.3)	85.6 (75.1-97.0)	112 (102-128)	1894
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	63.6 (<LOD-72.3)	657
20 years and older	*	< LOD	< LOD	< LOD	61.9 (56.7-66.9)	92.0 (80.8-102)	119 (103-132)	1237
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	73.6 (68.7-83.1)	94.7 (81.7-103)	910
Females	*	< LOD	< LOD	< LOD	62.6 (<LOD-68.5)	102 (86.0-118)	129 (118-155)	984
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	61.2 (<LOD-69.0)	97.7 (81.2-112)	132 (105-164)	621
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	58.1 (<LOD-67.7)	95.0 (72.8-110)	125 (101-183)	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	58.9 (<LOD-64.5)	84.9 (72.0-97.0)	106 (96.7-121)	709

< LOD means less than the limit of detection, which averaged 24.7 pg/g of lipid (SD 7.8, maximum value 55.9).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 79. 1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	32.6 (29.2-36.6)	56.7 (51.0-64.4)	74.0 (69.1-79.4)	1885
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	26.7 (20.3-29.3)	648
20 years and older	*	< LOD	< LOD	< LOD	36.1 (32.5-39.8)	62.8 (55.0-68.3)	75.6 (71.1-82.8)	1237
Gender								
Males	*	< LOD	< LOD	< LOD	31.5 (25.7-35.6)	54.8 (47.0-62.8)	71.1 (63.8-77.7)	908
Females	*	< LOD	< LOD	< LOD	34.9 (29.3-39.4)	61.2 (51.9-68.3)	74.9 (69.2-90.4)	977
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	20.9 (<LOD-25.0)	43.3 (33.9-52.6)	58.0 (49.5-64.8)	624
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	31.8 (26.6-40.9)	56.7 (45.2-72.4)	81.6 (66.2-94.1)	402
Non-Hispanic whites	*	< LOD	< LOD	< LOD	35.5 (30.7-39.4)	60.9 (53.6-67.7)	74.3 (68.4-82.4)	703

< LOD means less than the limit of detection, which averaged 7.5 pg/g of lipid (SD 3.1, maximum value 20.1).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 80. 1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1870
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	642
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1228
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	895
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	975
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	618
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	396
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	701

< LOD means less than the limit of detection, which averaged 7.6 pg/g of lipid (SD 3.2, maximum value 20.3).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 81. 1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1915
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	659
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1256
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	920
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	995
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	717

< LOD means less than the limit of detection, which averaged 5.3 pg/g of lipid (SD 2.2, maximum value 14.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 82. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1898
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	658
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1240
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	912
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	986
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	630
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	404
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	709

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 1.8, maximum value 12.1).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 83. 1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1884
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	652
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1232
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	904
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	980
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	623
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	404
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	705

< LOD means less than the limit of detection, which averaged 12.6 pg/g of lipid (SD 5.7, maximum value 35.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 84. 1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	14.7 (<LOD-17.0)	19.5 (17.4-22.3)	1709
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	17.7 (<LOD-22.9)	24.0 (18.6-29.6)	600
20 years and older	*	< LOD	< LOD	< LOD	< LOD	14.2 (<LOD-16.4)	18.4 (16.0-22.4)	1109
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	16.3 (13.9-18.5)	21.0 (18.5-24.7)	815
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	17.5 (14.8-19.7)	894
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	19.7 (<LOD-26.0)	570
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	22.4 (15.3-28.2)	28.2 (23.8-29.8)	359
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	17.4 (15.5-18.5)	636

< LOD means less than the limit of detection, which averaged 5.2 pg/g of lipid (SD 2.1, maximum value 13.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 85. 1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1890
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	657
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1233
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	908
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	12.9 (<LOD-14.7)	982
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	14.3 (<LOD-15.1)	399
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	703

< LOD means less than the limit of detection, which averaged 4.7 pg/g of lipid (SD 2.0, maximum value 12.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 86. 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1898
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	656
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1242
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	913
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	985
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	625
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	708

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 2.0, maximum value 12.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 87. 1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1875
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	645
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1230
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	894
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	981
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	620
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	400
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	699

< LOD means less than the limit of detection, which averaged 4.6 pg/g of lipid (SD 2.0, maximum value 12.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 88. 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1922
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	663
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1259
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	920
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1002
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	637
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	717

< LOD means less than the limit of detection, which averaged 5.0 pg/g of lipid (SD 2.1, maximum value 13.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 89. 2,3,4,6,7,8,-Hexachlorodibenzofuran (HxCDF)   (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1884
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	652
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1232
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	900
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	984
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	614
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	704

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 2.0, maximum value 12.9).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 90. 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	15.9 (13.8-17.0)	1895
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	656
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	16.1 (13.9-17.2)	1239
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	13.8 (<LOD-15.4)	906
Females	*	< LOD	< LOD	< LOD	< LOD	13.1 (<LOD-15.5)	16.7 (15.5-18.4)	989
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	16.3 (13.2-19.2)	400
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	15.5 (13.7-17.1)	706

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 2.0, maximum value 12.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

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Table 91. 2,3,7,8-Tetrachlorodibenzofuran (TCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1903
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	660
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1243
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	912
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	991
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	628
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	707

< LOD means less than the limit of detection, which averaged 4.6 pg/g of lipid (SD 1.8, maximum value 11.9).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 92. 3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	34.3 (31.9-37.5)	44.5 (40.3-49.1)	1888
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	648
20 years and older	*	< LOD	< LOD	< LOD	< LOD	36.4 (34.0-40.0)	47.8 (42.5-51.2)	1240
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	36.2 (32.8-40.0)	44.3 (40.0-49.6)	908
Females	*	< LOD	< LOD	< LOD	< LOD	34.0 (29.8-38.0)	46.5 (38.6-51.1)	980
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	31.0 (28.1-35.6)	622
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	40.3 (30.8-47.3)	51.1 (42.6-63.9)	403
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	34.6 (32.4-38.7)	45.3 (40.3-50.9)	709

< LOD means less than the limit of detection, which averaged 9.9 pg/g of lipid (SD 4.3, maximum value 27.0).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 93. 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	28.5 (25.9-31.5)	53.2 (46.8-59.1)	80.5 (65.0-98.6)	1896
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	23.8 (<LOD-27.5)	30.6 (23.8-38.6)	658
20 years and older	*	< LOD	< LOD	< LOD	30.8 (27.8-34.9)	57.1 (50.6-65.5)	89.5 (68.3-104)	1238
Gender								
Males	*	< LOD	< LOD	< LOD	25.4 (<LOD-28.6)	41.6 (34.8-47.9)	61.9 (47.9-79.2)	911
Females	*	< LOD	< LOD	< LOD	33.3 (28.3-38.9)	59.4 (53.6-75.1)	96.7 (75.9-110)	985
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	23.8 (<LOD-29.0)	42.7 (37.6-51.8)	66.1 (54.8-74.0)	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	30.3 (25.8-41.4)	67.4 (48.9-104)	120 (75.1-203)	404
Non-Hispanic whites	*	< LOD	< LOD	< LOD	28.3 (23.5-31.9)	50.4 (41.6-56.6)	67.8 (57.1-94.1)	704

< LOD means less than the limit of detection, which averaged 9.0 pg/g of lipid (SD 3.6, maximum value 23.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 94. 3,4,4',5-Tetrachlorobiphenyl (PCB 81)   (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1883
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	651
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1232
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	900
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	983
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	621
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	405
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	699

< LOD means less than the limit of detection, which averaged 25.8 pg/g of lipid (SD 10.7, maximum value 68.4).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.